Coastal Hazards

Chapter 11

Learning Objectives

- Understand ***coastal processes***, such as ***waves, beach forms and processes, and rising sea level***
- Understand ***coastal hazards***, such as ***rip currents and erosion***
- Know what ***geographic regions are at risk for coastal hazards***
- Understand the ***effects of coastal processes***, such of ***coastal processes, rip currents, coastal erosion, and rising sea level***
- Recognize the ***linkages between coastal processes and other natural hazards***
- Know the ***benefits derived from coastal processes***
- Understand how ***human use of the coastal zone affects coastal processes***
- Know what we can do to ***minimize coastal hazards***
- Understand the ***adjustments that can be made to avoid damage from coastal erosion and rising sea level or personal injury from strong coastal currents***

Introduction to Coastal Hazards

- Overall, ***coastal topography is greatly influenced by plate tectonics***
  - Difference in where you live
    - The ***east coast*** of the US and Canada is considered to be ***tectonically passive*** because it is not close to a convergent plate boundary, although there are ***still some coastal hazards***
    - The ***west coast*** of the US and Canada, including Alaska, is ***tectonically active*** along ***the transform boundary of the San Andreas fault and the convergent boundaries of the North American, Juan de Fuca and Pacific plates***. These ***convergence and strike-slip zones increase*** the coastal hazards in this area
- Unfortunately, these ***coasts are heavily populated***
- Once again people tend to ***build their cities in the way of hazards***

Hazardous Coastal Processes

- ***Coastlines extend for hundreds of thousands of miles***
- Every kind of ***structure, relief, and topography*** can be found along coastlines
- ***Distinctiveness of the coastal environment***
  - It is the ***interface of three major spheres***
    - ***Lithosphere, hydrosphere, and atmosphere***
    - ***Coasts are dynamic and highly energetic, restless motions of the waters***

Introduction to Coastal Hazards

- The most **serious coastal hazards** are:
  - ***Strong coastal currents*** including:
    - *Rip Currents* generated in the surf zone
    - *Tidal currents* in narrow bays and channels
  - ***Coastal erosion***, which continues to produce considerable property damage that requires human adjustment
  - ***Storm surge*** from *tropical and extratropical cyclones*, which claims many lives and causes enormous amounts of property damage every year
  - ***Tsunamis***, which are *particularly hazardous to coastal areas* of the *Pacific Ocean*

Coastal Processes

Waves

- Affect only a ***tiny fraction*** of the total Earth's surface
- **Creates a landscape almost totally different from any other**
  - ***Waves are agents of erosion***
  - ***Currents are agents of transportation and deposition***
  - ***Creates notable land features***
    - Such as: *Rocky cliffs, headlands, beaches, and sandbars*
- ***Beaches are the area of transition*** between shoreline and water
- ***Waves that batter the coast*** are generated by offshore winds, sometimes thousands of miles away from the shore they reach
- ***Wind blowing over the water produces friction along the water's surface***
- As this ***friction is created, it transfers some of its energy to the water and produces waves***
- The ***waves then expend their energy at the shoreline***

Waves

- **Waves vary in their Size and Shape**
- **The size of the waves in the ocean or on a lake depends** on a combination of:
  - ***The velocity of the wind***: *the stronger the wind speed, the larger the waves*
  - ***The duration of the wind***: *the longer lasting the wind, during storms, the more energy is forced on the water, creating larger waves*
  - ***The distance that the wind blows across the water surface: this is the fetch***. *A longer fetch allows larger waves to form. This is more effective in the ocean than in a lake*

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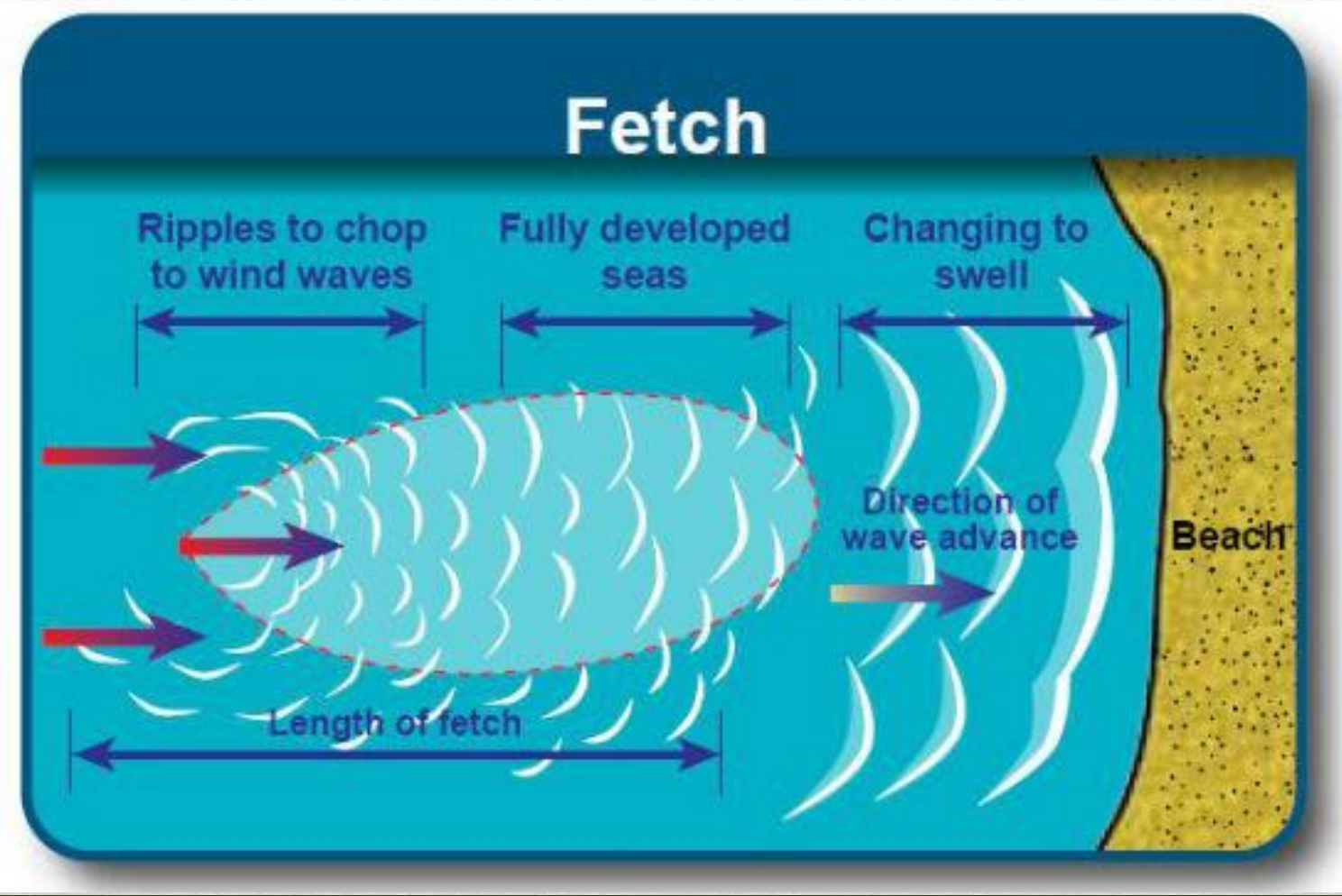
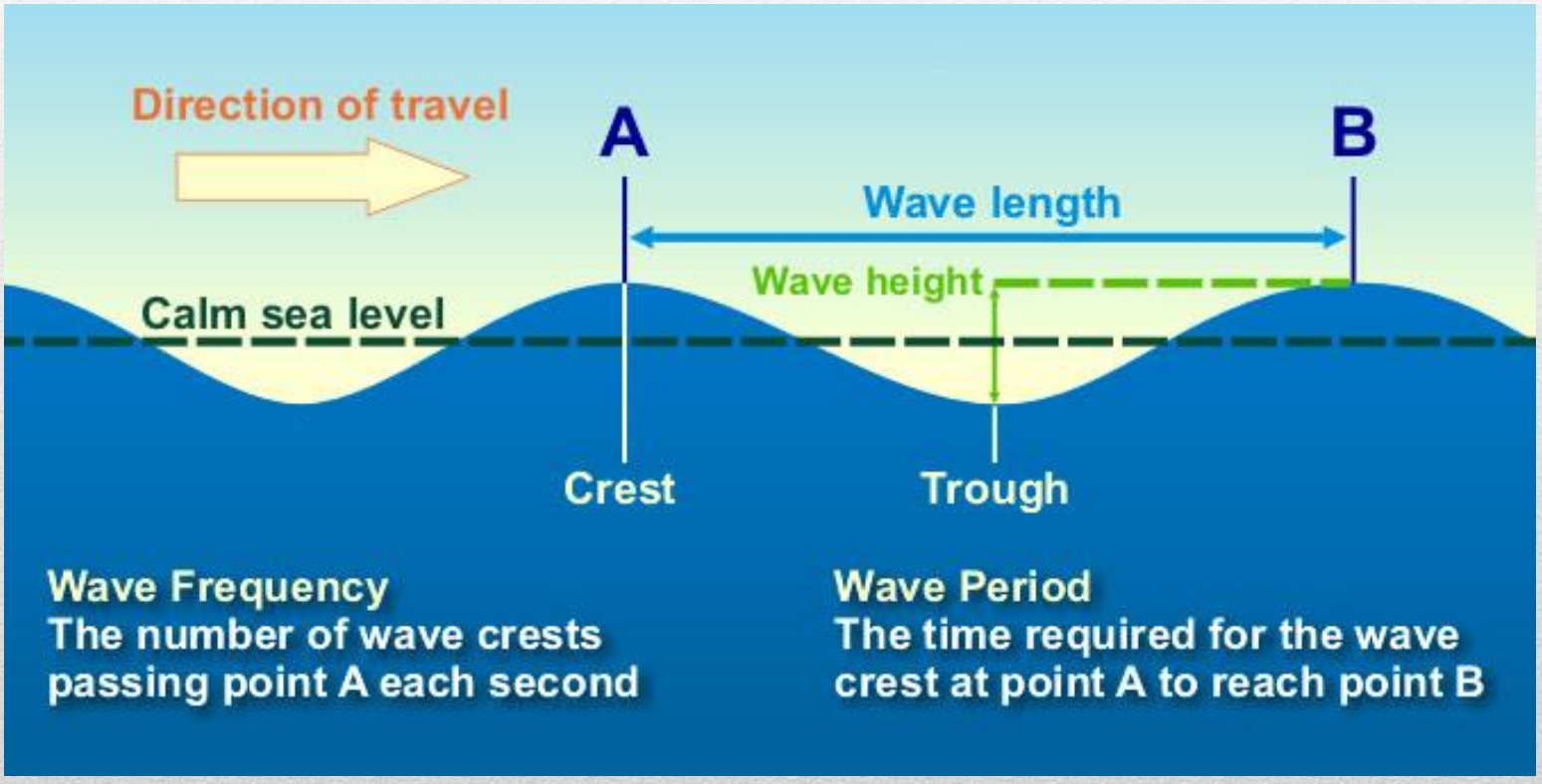
Waves


Fetch
Ripples to chop to wind waves
Fully developed seas
Changing to swell
Direction of wave advance
Beach
Length of fetch

Parts and Measurements of Waves

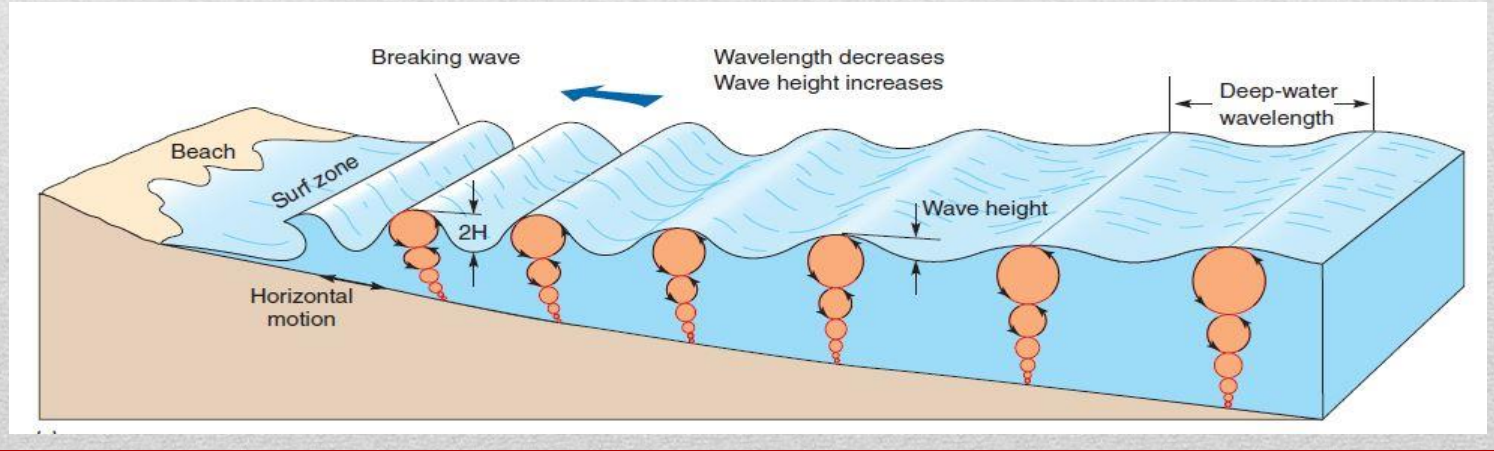
- ***Wave amplitude-*** ½ the height of the vertical distance from still water either to the crest or the trough
- ***Waves often travel great distances across deep water with little change in the shape or speed***
- **BUT *when a wave reaches shallow water changes happen:***
- ***When water depth becomes equal to half the wave length, wave motion begins to be effected by the frictional drag or the sea bottom***

Parts and Measurements of Waves



Wave Motion

- **Wave Motion**
  - The ***form of the wave as it moves through the water***
  - ***Water itself shifts only slightly***
  - In ***shallow water waves crests and breaks***
  - ***Wind generates most waves***
    - Set in ***motion largely by the friction of air blowing across the water***
    - This is a ***transfer of energy from the wind to the water***



Kinds of Waves

- **Two Major Kinds of Waves**
  - **Water waves**
  - Generated by ***friction*** on the water surface
    - ***Develop into considerable size and turbulence***
    - ***Limited existence and don't travel far***
  - **Swells**
    - Waves that ***escape the influence of the generating wind***
    - ***Travel enormous distances***
  - Small number of waves not caused by wind
    - ***Tidal Surge***
    - ***Rogue Waves***

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Waves of Oscillation and Transition

- **At a given point on top of water surface there is a point of oscillation**
  - **Oscillation** – move back and forth over one place
  - These are **Waves of Oscillation**
- **Resulting from horizontal movement of the surface water**
  - These are **Waves of Transition**

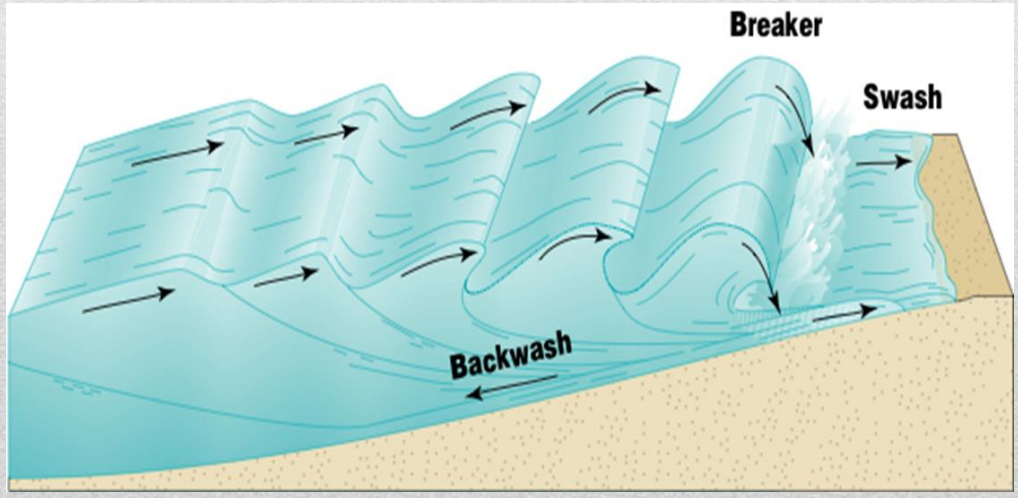
Waves of Transition

- **Waves of Transition**
  - **As friction retards the movement of the wave:**
    - **Waves bunch together**
    - **Decrease in wave length**
    - **Increase in height**
    - **Drag increases- until instability**
    - **Wave breaks – resulting in**
      - Whitewater surf
      - Plunging forward as a breaker
      - Surging up the beach without cresting

Waves of Transition

Waves of Transitions

- After breaking the water becomes turbulent – **Swash washes up the shore**
- Carries sand and rock particles onto the beach or rocky headlands or sea cliffs
  - **The reverse of Swash is called Back Wash**



Wave Variations along a Coastline

- As waves begin to approach the shore, their ***sizes varies***
- These variations are caused by ***the irregularities of the offshore topography***
  - ***Irregular coastlines*** have small rocky peninsulas known as ***headlands***
  - The *shoreline between the headlands* could be ***relatively straight or curved***
  - Underwater, the *offshore topography surrounding the headland is similar to the land above the water*, ***growing shallow at headland and at the beach***
  - As the ***wave approaches the shore, wave refection happens and the coastline is changed***

Effects of Wave Refraction

- **Wave Refraction**
  - Where waves ***change direction and change the shoreline***
    - This happens ***when waves do not approach a shore exactly parallel***
    - Part of the ***wave arrives sooner- slows faster and "bends" the wave***
    - The tends ***to smooth the coastal outline by wearing back the headlands and increasing sediment accumulation in the bays***

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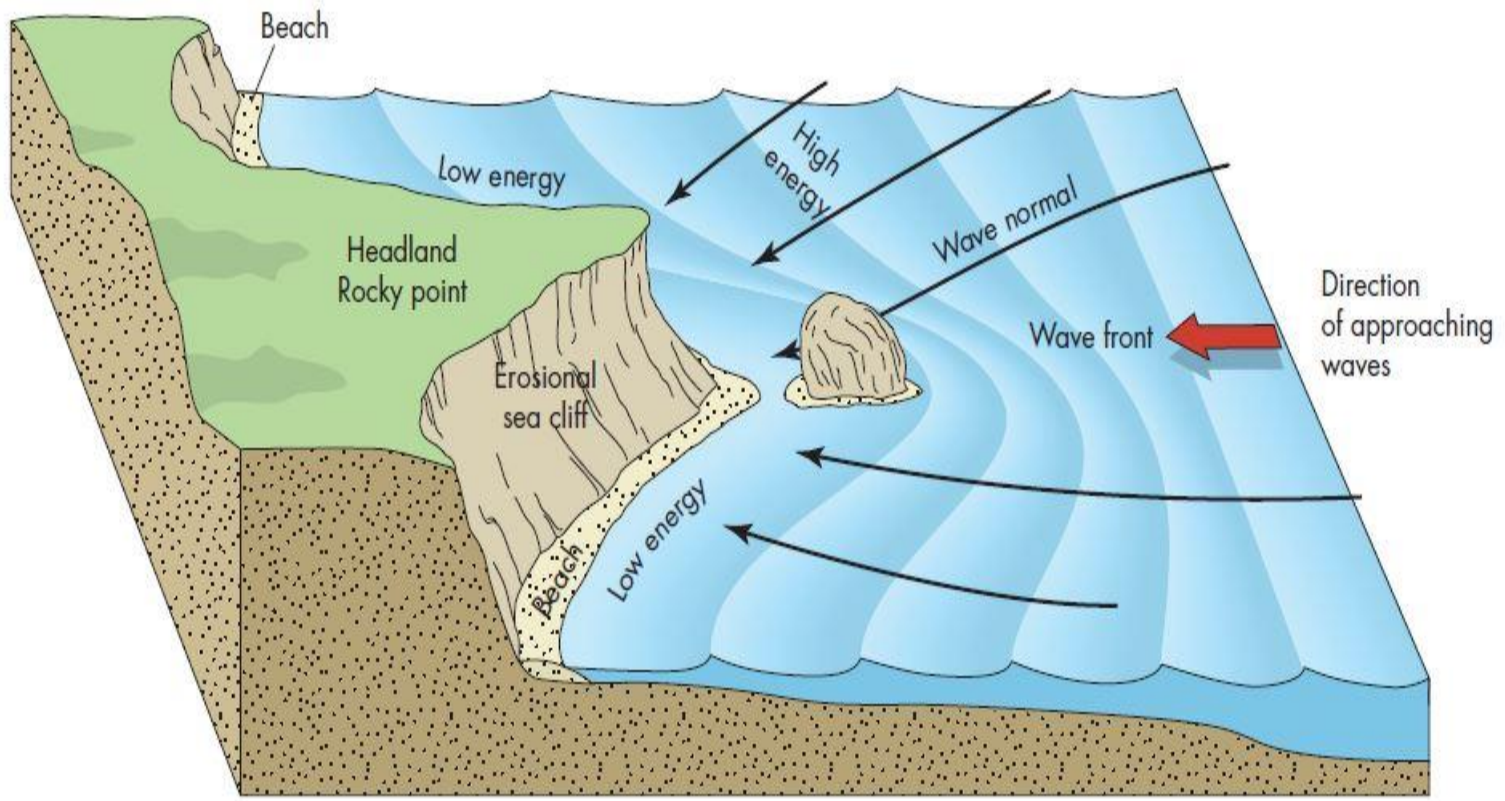
Wave Refraction



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Wave Refraction

- ***Notable coastal erosion is caused by this wave refraction***
  - ***Incessant pounding of the waves wears away the shoreline***
    - ***Speed coupled with mass of water and rock particles helps with this process***
  - Another dimension of ***wave erosion*** is ***air being forced into cracks***
    - This ***pneumatic action is often very effective***
  - ***Chemical action*** also an ***effective erosion***
    - This action ***dissolves some rocks***

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Breaking Waves

- ***Breaking Waves***

  - Waves *vary in how they break along a coastline*. They may ***peak up quickly and plunge*, or surge, or they gently spill**, *depending on conditions*
    - ***Plunging Breakers – form on steep beaches and tend to be more erosive***
    - ***Spilling Breakers – waves that spill on wide nearly flat beaches and tend to deposit sand***
  - The type of ***breaker changes seasonally and with changes in the underwater slope***

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Breaking Waves

(b)

Beach Landforms

- A ***beach is a landform consisting of loose material***
- Beaches can be ***composed of a variety of loose materials***
  - The ***color and composition of beach sand is directly tied to the source of the sand***
    - This ***material can composed*** of: ***sand, gravel, volcanic rock, shell, or coral, and minerals such as quartz and feldspar***

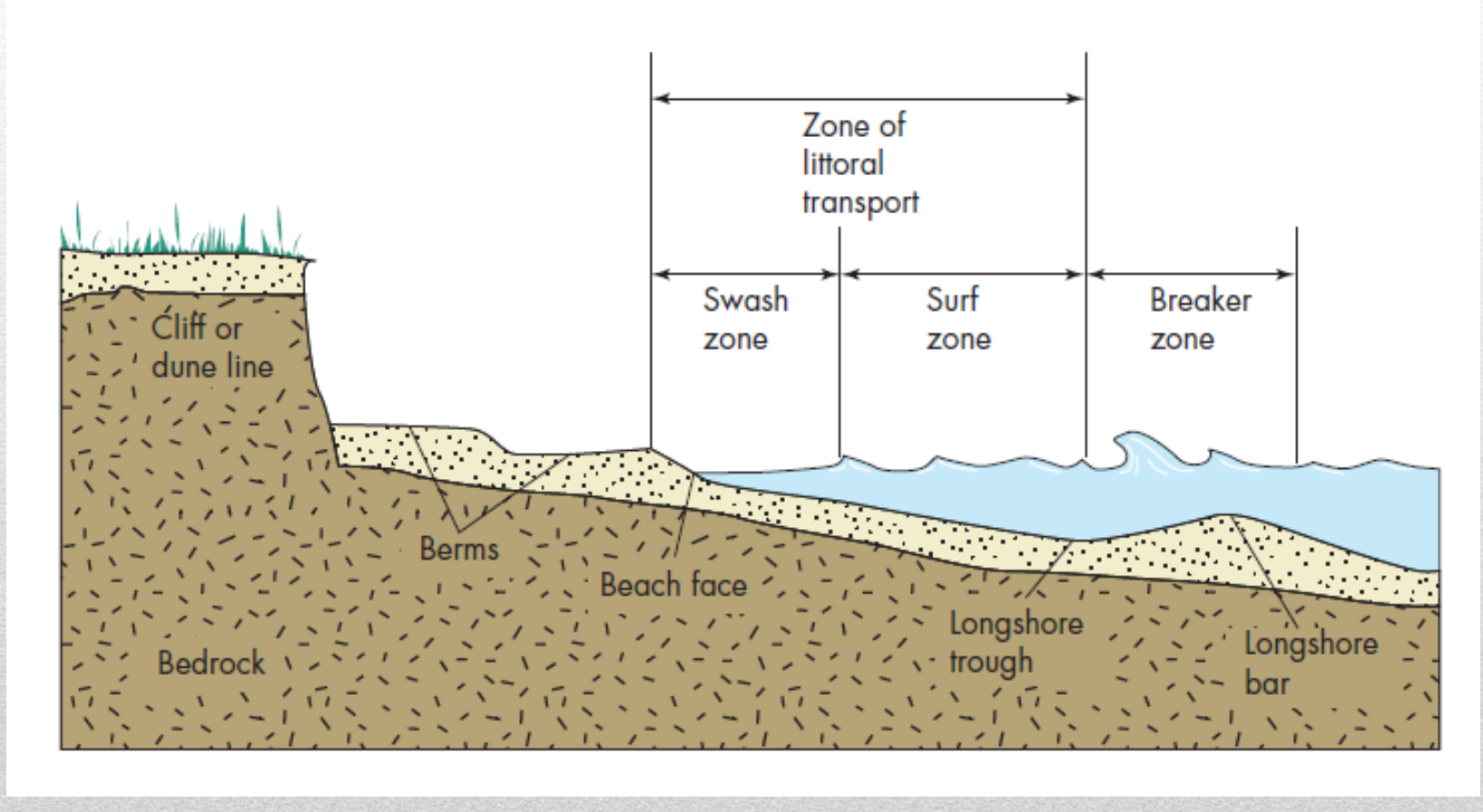
Beach Features and Processes

- The ***Beach Features Onshore and Processes***
  - ***Onshore features:*** Landward is generally either a ***sea cliff*** along a ***sea shore*** and a ***bluff*** along a ***lakeshore***, a line of ***sand dunes***, or a line of ***permanent vegetation***
    - The ***erosion of rock or unconsolidated sediment creates sea cliffs and bluffs***
    - ***Coastal sand dunes are created by the deposition of windblown beach sand***
  - Onshore beaches are divided into ***two areas***:
    - Slopes landward are called ***berms***
      - These are the ***flat backshore areas formed by deposition of sediment as waves rush up and expend the last of their energy***
    - Slopes toward the water are called the ***beach face***
      - It is here that we find the ***swash zone of the wave***

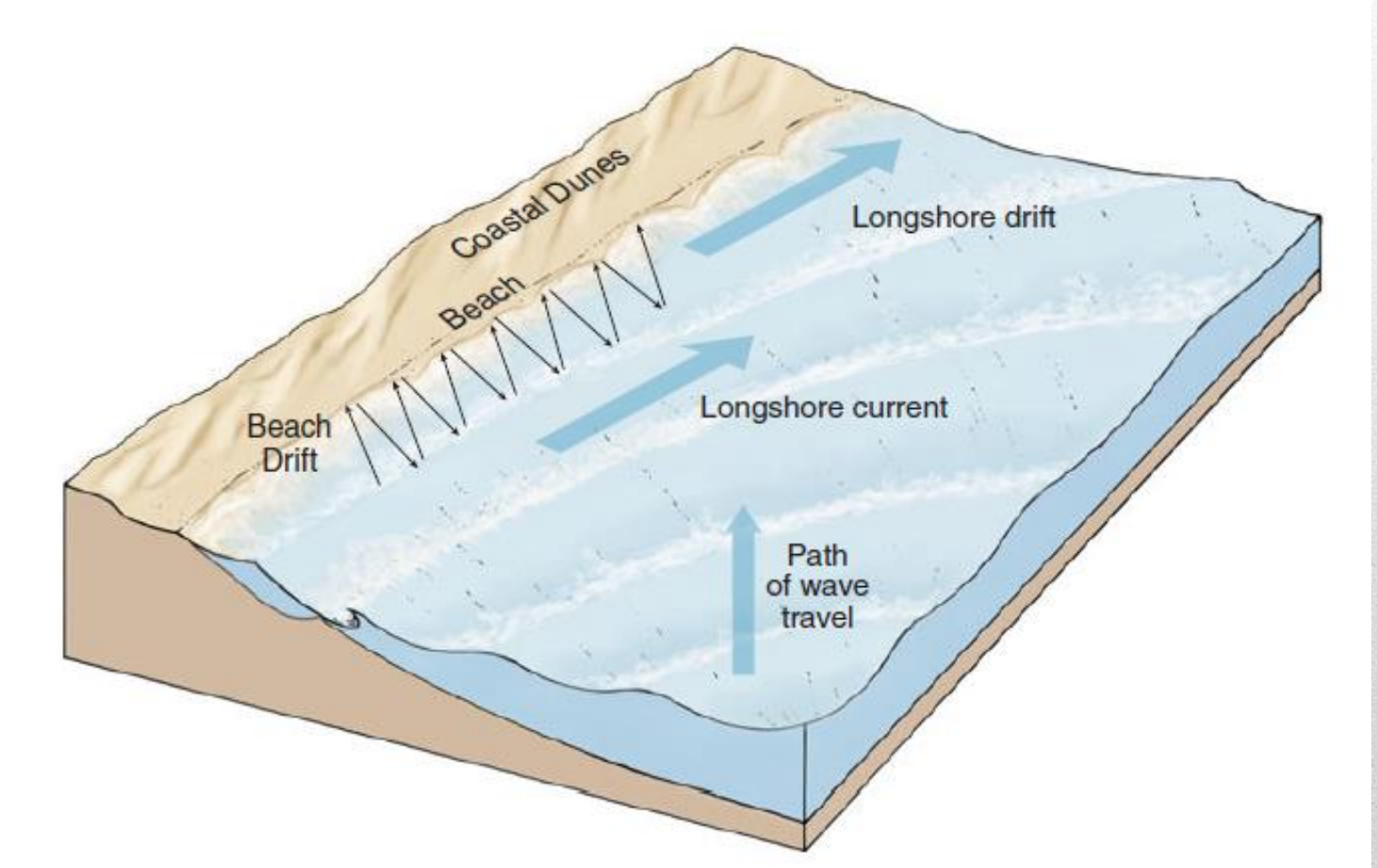
Beach Features and Processes

- The ***Beach Features Offshore and Processes***
  - ***Offshore features***: Directly from the swash zone ***there are two distinctive zones*** in the water: ***the surf zone and the breaker zone***
    - ***Surf zone*** is the ***portion of the nearshore environment where turbulent translational waves move toward the shore after the incoming wave breaks***
    - Beyond the surf zone is the ***Breaker zone***, the ***area where incoming waves be come unstable, peak, and break***
  - *Conditions on the water surface are reflected in the underwater topography*
  - ***Underwater topography of offshore beaches***
    - ***A longshore bar***, ***forms beneath each line of breakers in the breaker zone***
    - ***Landward from the longshore bar is a longshore trough*** which *forms on wave and current action*

Beach Features and Processes



Beach Drift and Longshore Current



Sand Transport

- ***Littoral Transport on the Beach***– *sand movement occurring parallel to the shoreline in the swash and surf zones*
  - ***Beach Drifting***
    - Involves the ***short distance shifting of sand in the swash zone***
    - Movement is in a ***zig-zaging movement of particles***
    - Moves because of the ***oblique direction of wave hitting the shore*** world
  - ***Longshore Drift***
    - The ***transport of sediment by ocean currents that flow essentially parallel to the shoreline***
    - These ***currents are the primary mechanism for littoral transport***

Sand Transport

- ***Littoral Transport on the Beach***

- These two types of drift, *beach drifting and longshore drifting* are called ***longshore currents*** occur when ***waves strike the coast at an angle***

- The terms ***updrift*** and ***downdrift*** are used to ***indicate the direction of the sediment movement or accumulation along the shore***

Sea Level Change

- The level of the sea at the shore is *constantly changing*
  - Some of these changes are from local processes
  - Other processes effect all the oceans around the world
- The **level of the sea** is referred to as the ***relative sea level***
  - Influenced by the movement of the land and the movement of water
  - These movements can be local regional or global
- ***Global Sea Level***, also called ***Eustatic Sea Level***, is controlled by processes that affect the ***overall volume of water in the ocean and the shape of the ocean basins***
  - Changes in the ***Eustatic sea level*** are one of many factors that cause the ***change in relative sea level***

Sea Level Change

- ***Global sea level rises or falls*** when the amount of ***water in the oceans increases or decreases*** OR if there is a ***change in the overall shape of the ocean basins***
  - ***Climate***, primarily the ***average air temperature***, is the ***dominant control on the amount of water in the ocean***
  - ***Air temperature influences*** both the ***average temperature of the ocean and the amount of water in the ice on the land.***
    - As the average temperature of the ocean ***increases***, the ***water expands***, as it ***cools***, the volume of ***water contracts***. This is referred to as ***thermal expansion or contraction***
    - ***Global warming or cooling*** is ***responsible for this phenomenon***

Sea Level Change

- Changes in air temperature also causes ***ice on the land to melt or snowfall to increase***

- Over geologic time spans, ***ocean basins change shape as the result of plate tectonic processes***

  - These *large scale processes* like ***sea floor spreading*** influence Eustatic sea level ***over long periods of time*** and ***are unlikely to be associated with the resent change in sea level***

Sea Level Change

- ***Relative Sea Level***

- *Superimposed on eustatic sea level* are the ***local or regional processes that influence the moment of land and water***

  - Land can rise or fall slowly as the Earth's crust respond to the weight of the now-melted Pleistocene glaciers or rapidly in response to tectonic movements

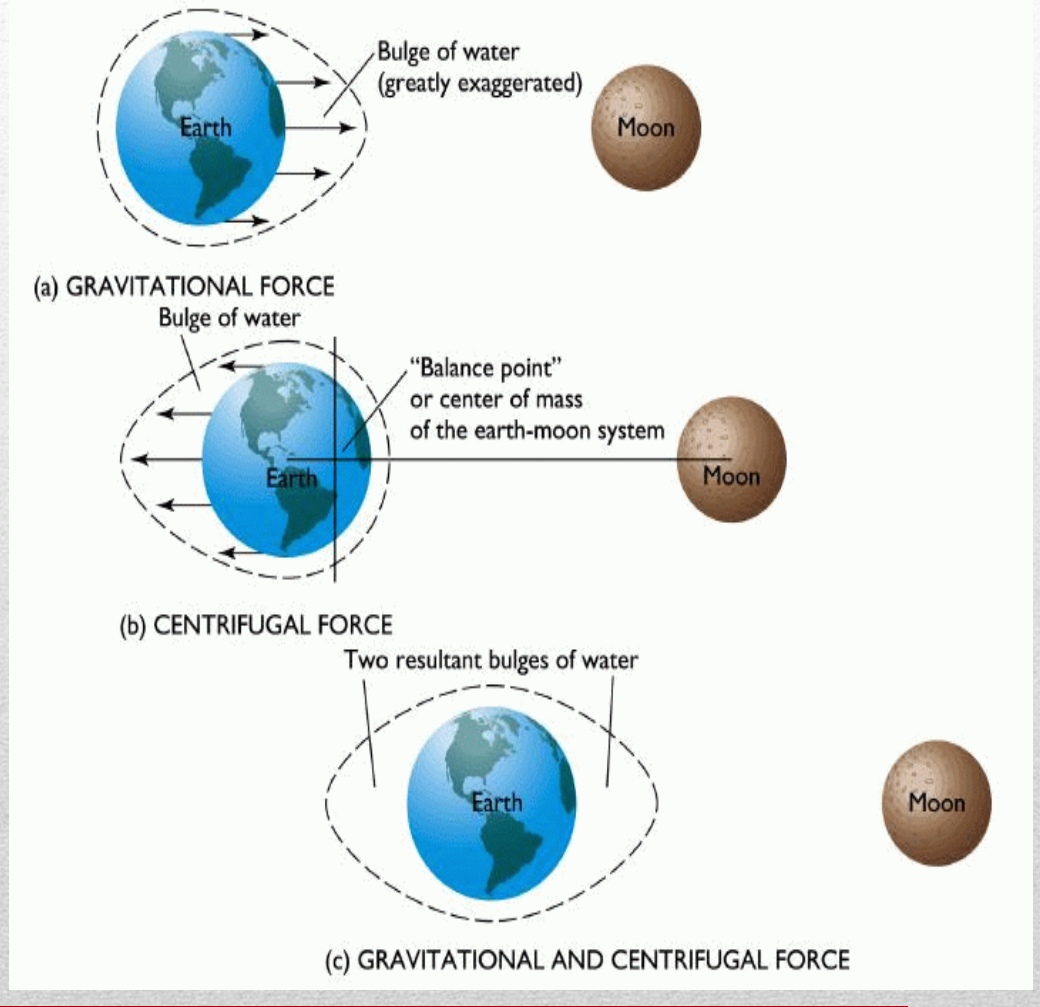
  - ***Movement of the shoreline*** is also ***influenced by the rates of deposition, erosion, or subsidence along the coast***

Sea Level Change

- ***Daily tides and weather conditions primarily control relative sea level***
  - The ***daily tides and weather conditions primarily control relative sea level***
    - ***Daily tides*** produced by the ***gravitational pull of the moon and to a lesser extent, the sun***
    - ***Tidal fluctuations are entirely predicable,*** but they can ***creat hazardous currents that affect the height of storm surges***

Tides

- ***Significant agents of erosions found*** only in:
  - *Narrow bays*
  - *Shallow seas*
  - *Passages between islands where strong currents scour the sea bottom and cliffs and shorelines*



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Changes in Sea Level & Lake Levels

- ***Weather conditions*** also can ***change relative sea level in a period of hours or days***

  - ***Changes in wind speed*** and ***atmospheric pressure influence the level of the*** sea
  - ***Wind speed*** has a ***greater effect*** than ***atmospheric pressure*** on ***relative sea level***
  - In ***open ocean***, ***high winds pile up water and increasing wave height***
  - This ***increases water level*** when the ***waves eventually reach the shore***
    - This causes a ***higher storm surge*** from ***tropical storms, hurricanes, extratropical cyclones crossing the coast***

Changes in Sea Level & Lake Levels

- In summary ***rapid changes in relative sea level contribute to coastal flooding and hazardous near shore currents***

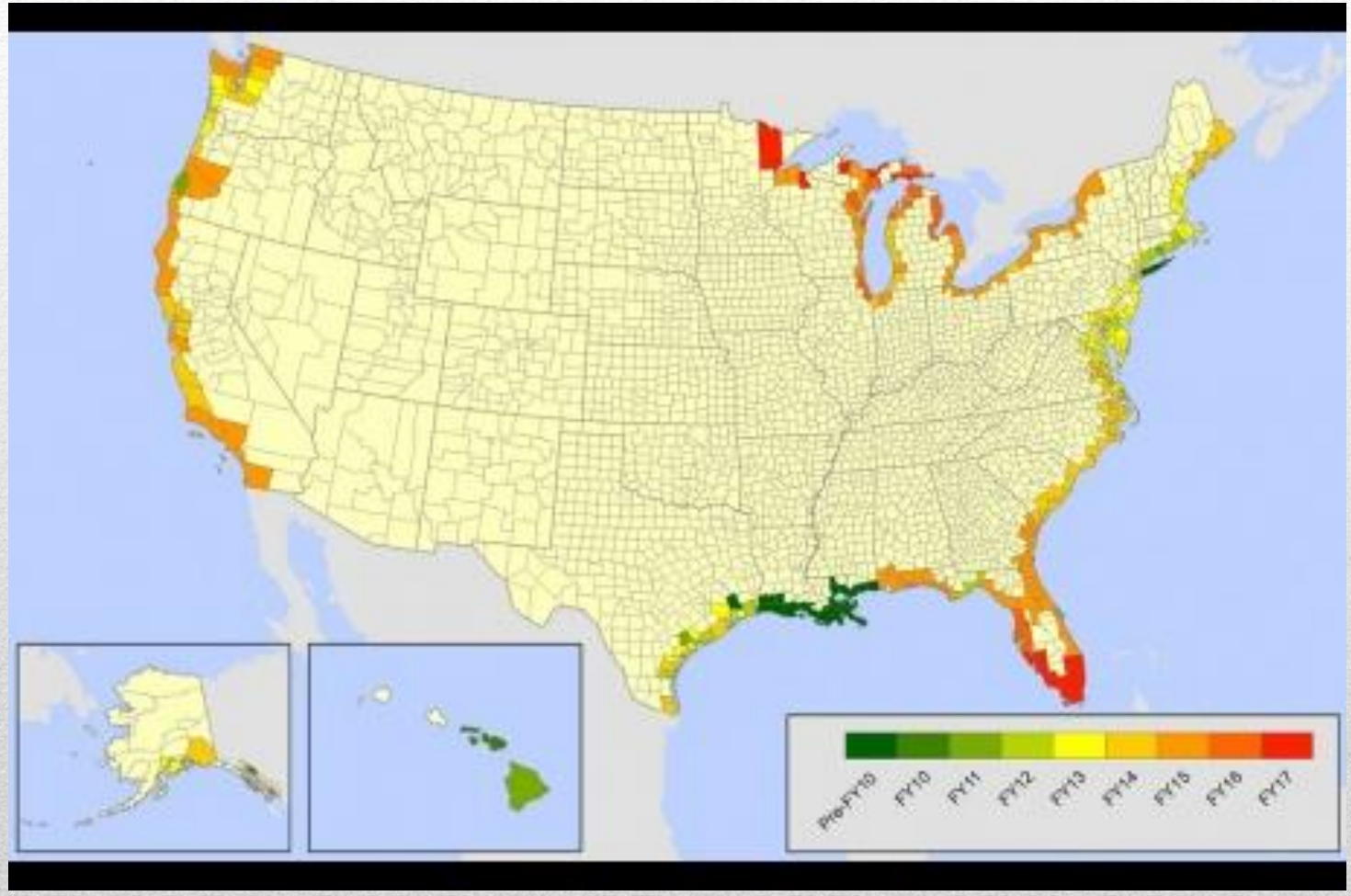
- Whereas, ***eustatic sea level over decades increases hazards from storm surge and coastal erosion***

  - This ***eventually leads to the rising sea level which threatens coastal cities and many islands***

Geographic Regions at Risk for Coastal Hazards

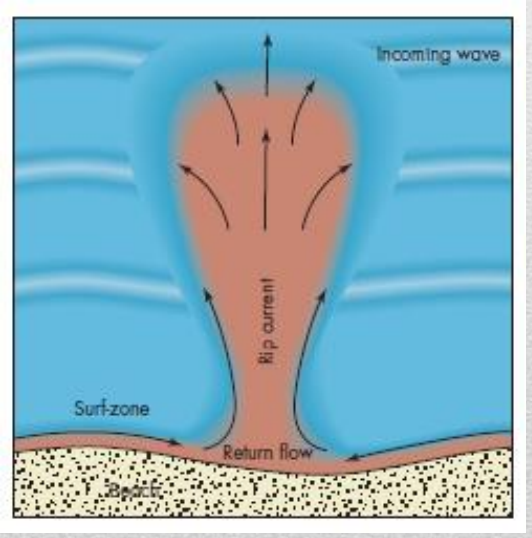
- ***Coastal hazards are present on both sea coasts and lake shores***
  - ***Nearshore currents, sea-level rise, and storm surge from cyclones and tsunamis*** are some of the coastal hazards
    - The ***Great Lakes of North America*** are *susceptible to coastal hazards because of their size*
    - Cyclones and tsunamis are generally ***absent in small lakes***
  - ***Coastal erosion*** is a more ***universal coastal hazard***
    - There are ***various causes for coastal erosion***
      - ***Rip Currents***
      - ***Tides***
- ***Coasts and islands*** that are close to sea level today are at the ***greatest risk for coastal hazards***

Geographic Regions at Risk for Coastal Hazards

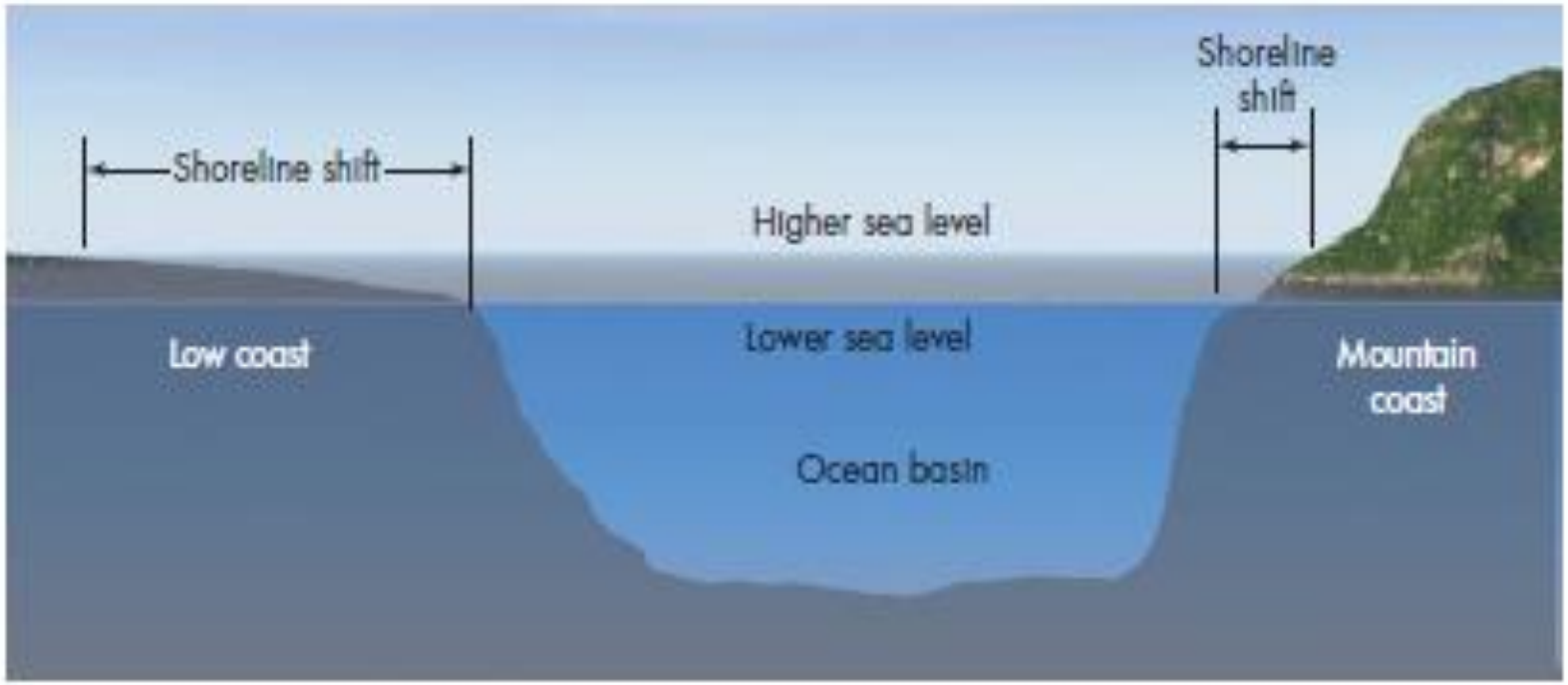


Rip Currents

- ***Rip Currents*** -- different from the other longshore currents –
  - Found along shorelines, powerful currents form that carry large amounts of water away from shore
  - Develop when a series of large waves pile up water between the longshore bar and swash zone
  - These currents do not pull you under the water, but they can carry you away from shore



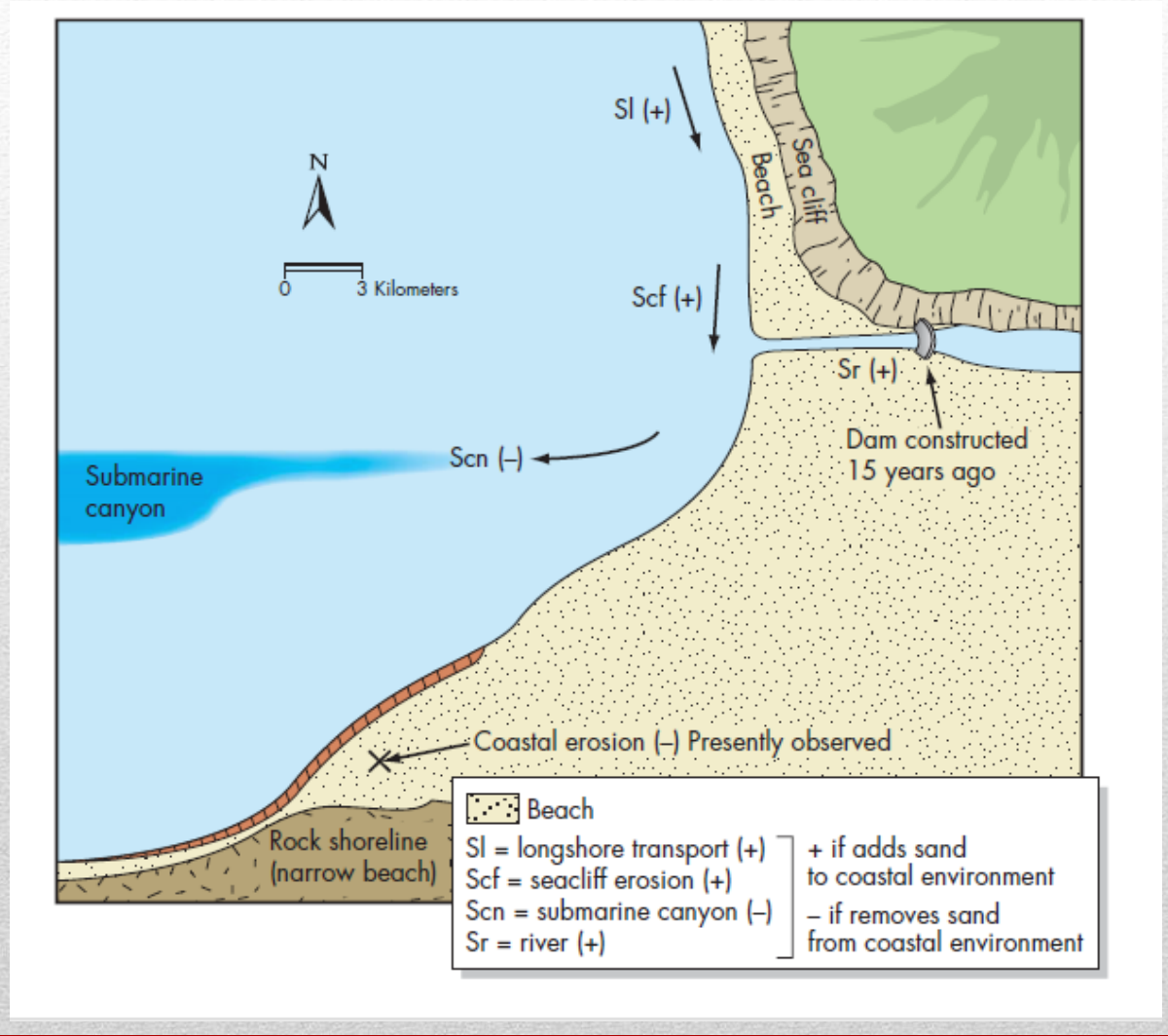
Rising Sea Level on Low Coastlines



Coastal Erosion

- As ***global sea level rises*** and ***extensive development continues*** on these *coastlines*; ***coastal erosion is recognized as a serious problem***
  - *Beach erosion* – or ***beach-budget*** -- much like a bank account – must be ***researched and identified***
    - If you take ***more out of the beach*** – eventually there ***won't be any beaches left***
    - If you build a ***budget for a beach***, you will keep the ***beach in tact***
  - ***How or what do we do about this*** — *look at it like a budget*
    - ***On a beach*** we look at ***input, storage,*** and ***output*** of sand or gravel
      - If the ***beach's loses*** are ***greater than its gains***, then ***erosion results***
      - If the ***beach's loses*** are ***less than its gains***, the ***beach grows by accretion of sand***
      - ***Evaluation of the beach budget over a set period of time to decide if change should be made***

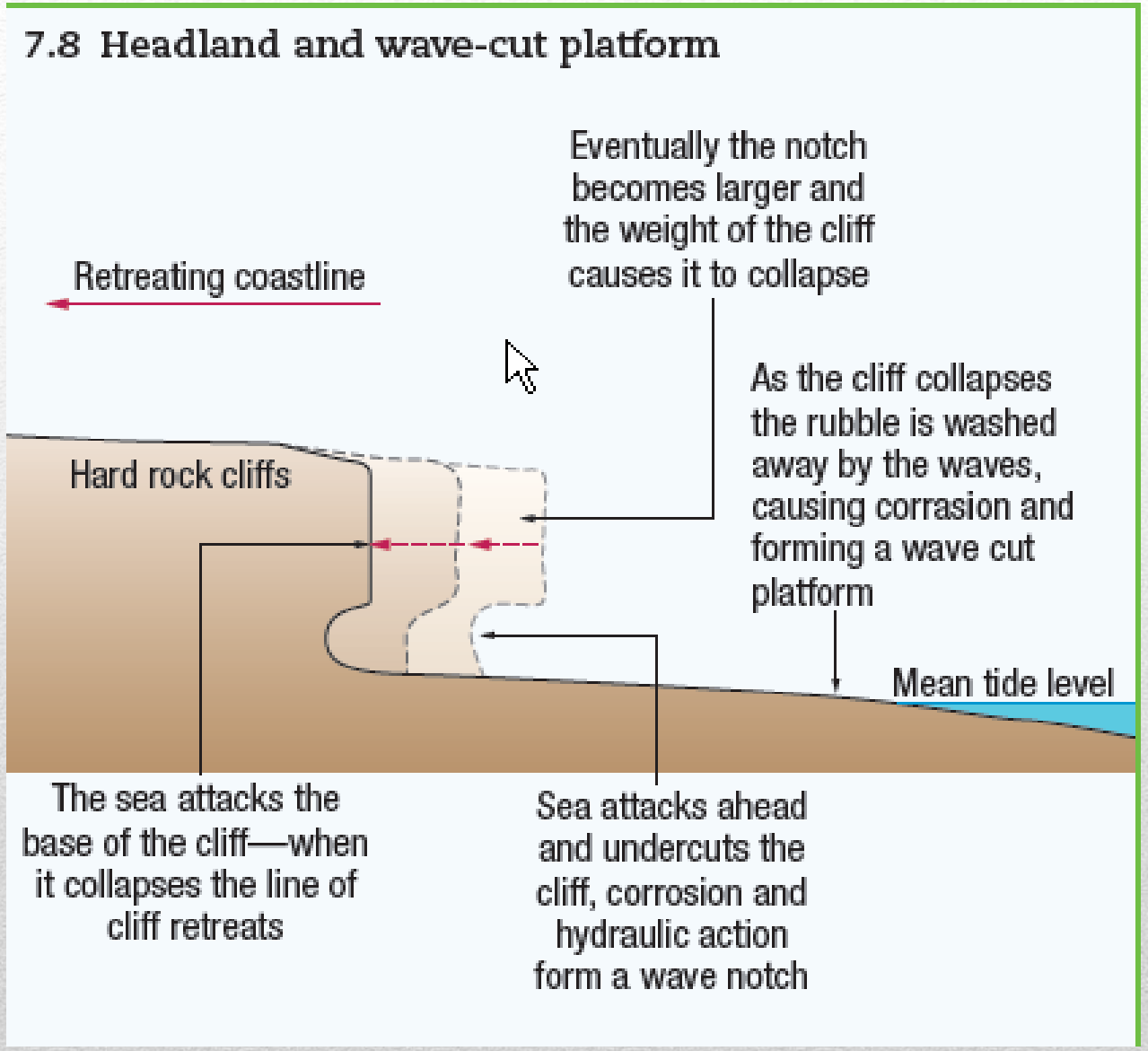
Beach Budget



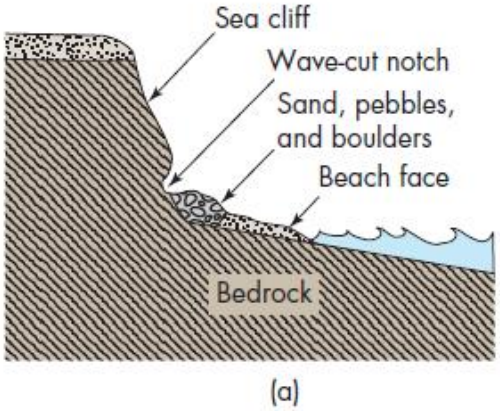
Cliff Erosion

- ***Cliff Erosion*** – Cliff erosion is caused from a combination wave actions and land erosion by running water and landslides.
  - This is also compounded by people who make poor development choices on cliffs
- How ***do cliffs erode***?
  - ***Cliffs erode*** like the *knickpoint on a stream or river*
    - As the ***wave action pound the cliff***, ***the cliff will begin to "retreat" through the hydrologic power of the pounding of the waves***
    - This not always easy to detect at low water, but easy to detect during high water

Cliff Erosion



Cliff Erosion



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Linkages with Other Coastal Process

- ***Coastal processes are often linked to other natural hazards, such as earthquakes, volcanic eruptions, tsunamis, cyclones, flooding, landslides, subsidence, and climate change***

- Besides natural hazards, there are the ***man-made hazards which seem to happen all to often.***
  - Looking at the ***latest oil spill in the Gulf of Mexico***
    - ***This oil spill*** destroyed beaches, killed wildlife, and destroyedd the wetlands found along the Louisiana Delta

- ***Other natural hazards that affect the coast***, such as: ***freshwater flooding of coastal plains, bays, and lagoons: and the mass wasting of cliffs along the ocean and lakes***

Natural Service Functions of Coastal Processes

- The ***beauty of coastal areas of the world*** are one of the ***natural services of the coastal processes***
- There is also a ***renewal of the ecosystems through the coastal processes***
- There are the ***development of coral reefs which are areas wonderful areas for fish and mammals to live in***
- These ***beaches along coasts also give us great recreational areas for swimming, surfing, sailing and fishing***

Natural Services of Coastal Processes

- ***Coral Coast***
  - ***Coral reefs*** or other ***type of coral line formation found around islands in the tropics***
  - ***Critical element in development of coral reefs is a group of entozoan animals called stony corals***.
    - Great Barrier Reef an example
- ***Volcanic coral reefs***
  - ***Coral animals accumulate around the volcano***
  - As ***coral increases the volcano sinks***
  - When ***volcano sinks completely the coral reef becomes an atoll***

Volcanic Coral Reef

Human Interaction with Coastal Processes

- **Human interference with natural shore processes has caused considerable coastal erosion**
- Most ***problems arise*** in areas that are ***highly populated and developed***
  - Efforts to stop ***coastal erosion*** involve ***engineering structures to impede the littoral transport***
  - These ***artificial barriers interrupt the movement of sand, causing beaches to grow in some areas and erode in others thus damaging valuable beachfront property***
  - This ***type of human interaction is especially prevalent in the coastal areas of the US***

Human Alterations on Coastal Areas

- ***There are many different structure and adjustment made to the coastal areas to alleviate the problems that were made by our intervention***
  - ***Dams*** - built so less sediment reaches the mouth of rivers
    - ❖Changes beaches
  - ***Artificial structures*** - built to stabilize beaches
    - ❖Reduces sediment transport down shore
    - ❖Dumping tons of sand up-current from beach, doesn't work
  - ***Groin*** – short wall or dam built from a beach to impede longshore currents and force sand deposition
    - ❖Problem erosion breaks down the groin
    - ❖A field of groins are built
  - ***Seawalls*** – Structures built on land parallel to the coastline to retard erosion and protect buildings from damage

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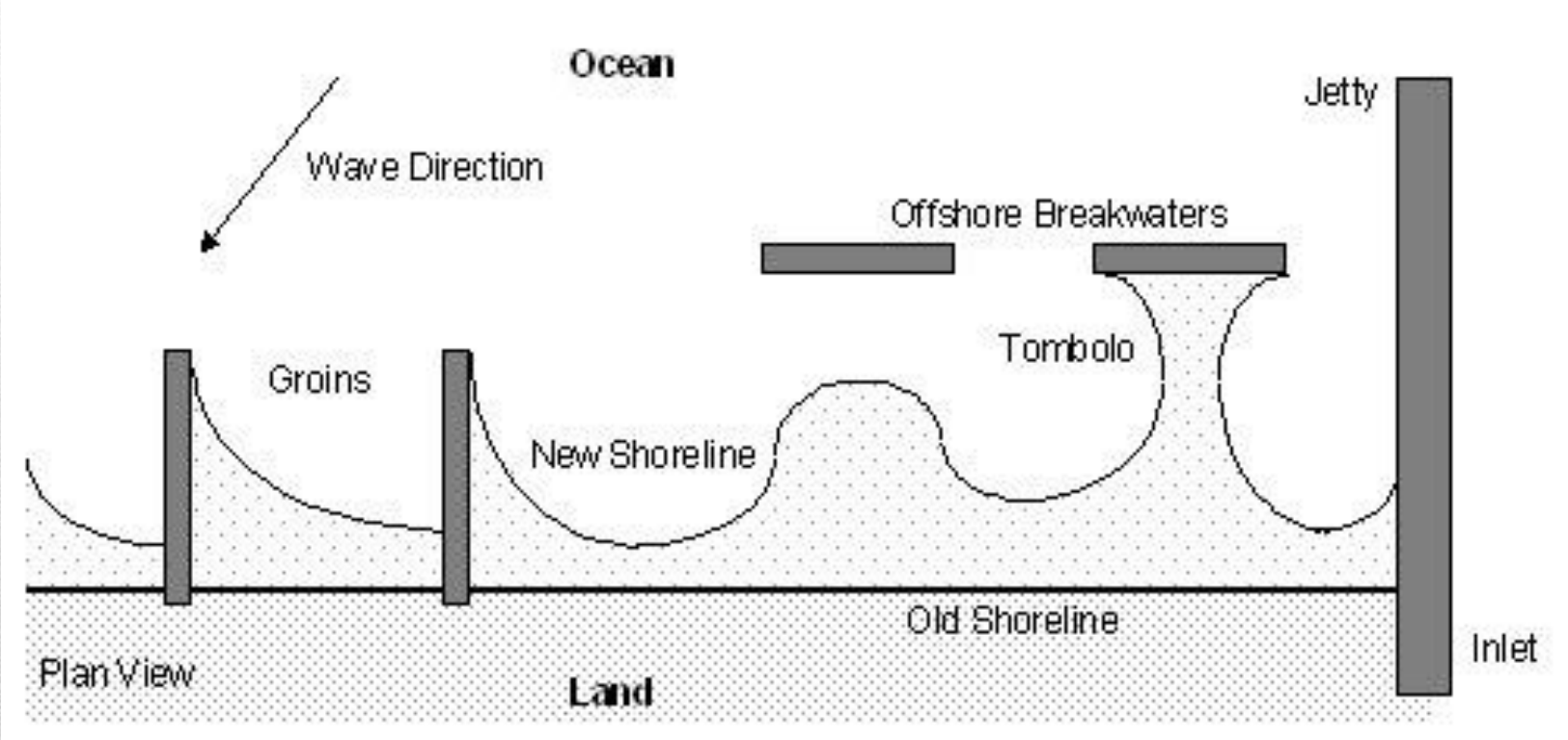
Human Alternations Coastal Areas

- ***Jetties*** – Built in pairs on either side of a river or harbor entrance
  - Confines the flow of water into a narrow zone
  - Keeping the sand in motion and inhibiting its deposition in the navigation channel
- ***Spits*** - Growing linear deposit of material attached to the land extending into open water in a down-current direction
  - ***Baymouth Bar*** – (bay barrier) a spit that progresses across a bay or form a lagoon
  - ***Tombolo*** – spit shape is caused by conflicting water movements- forms a hook
- ***Barrier Island*** - A long narrow sandbar built up in a shallow offshore waters
  - Results from the *heaping up of debris where long waves begin to break in shallow waters of continental shelves*
- ***Lagoon*** - A body of water between the mainland and a spit or baymouth bar of salty or brackish water

Human Alternations Coastal Areas



Perception of and Adjustment to Coastal Hazards

- People generally ***perceive land as being stable and permanent***
- This is appropriate for many areas, but ***coastlines are dynamic, shorelines erode, accumulate, and move in time frames of months and years***
- Even though ***people are told of the dangers of the erosion of coastal areas, they keep building closer, they treat them with no care, and they don't realize the damage they do in a very short time***

Adjustment to Coastal Hazards

- There are ***ways we can adjust to shorelines with strong currents, coastal erosion, and rising sea level***.
- There are ***three adjustments that will help with coastal erosion categories***

  - ***Beach nourishment that tends to imitate natural processes –the "soft solution"***
  - ***Shoreline stabilization through structures, such as groins and seawalls– "hard solution"***
  - ***Land-use change that attempts t avoid the problem by not building in hazardous areas or by relocation of threatened buildings – the "managed retreat solution."***